AN EXPERIMENTAL STUDY OF THE BEHAVIOR AGREEMENT AMONG THE ANIMALS OF AN ANIMAL COMMUNITY.

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PAGE.

I. INTRODUCTION.

On the basis of literature, naturalistic observation, and preliminary experiments the writer has several times stated ('13) that a physiological agreement exists among the animals of animal communities. The object of this investigation was to determine the extent and character of such agreement with particular reference to the rapids community of a large creek. It is the purpose of this paper to show that, considering the community as a whole, there is (1) a *general agreement* in reactions to certain factors, (2) *disagreement* in *respect* to factors differing in intensity *vertically* and (3) a *sharp difference* between *different* communities.

The rapids community was selected for detailed study because it was anticipated that the animals were governed mainly by

mechanical stimuli which lend themselves to experiment more readily than many others. The pool community was studied in a *preliminary* way to bring out the difference between different communities.

Over two hundred experiments were performed by Chas. W. Finley and the writer working independently. It was originally hoped that these might be used in this discussion but the difficulty of adjusting conditions to which eight or more entirely different animal species can respond, is great, and finally the use of the first lot of experiments as a basis for comparison was decided to be impracticable. This was due to faulty conditions which gave bad results in the case of one or more species. However these experiments gave a close knowledge of the behavior of each species, so that when accurate methods were devised only sufficient experiments to give typical results proved necessary. These show experiments were conducted with much care and are the only ones presented.

II. MATERIAL.

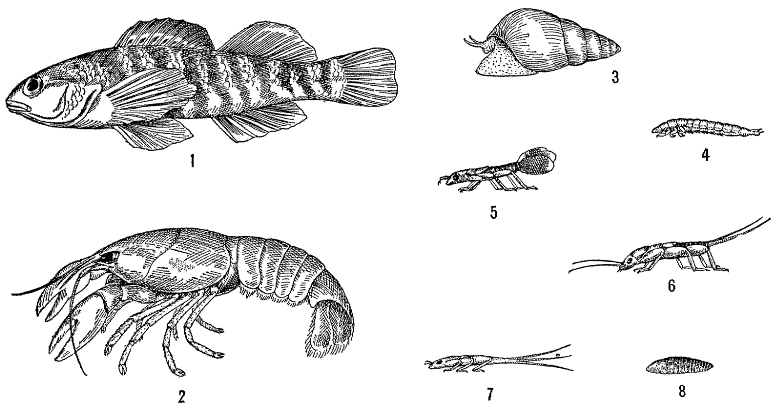
The material used were the species found habitually in rapids and pools of Hickory Creek at New Lenox, Ill. (Shelford '13). All the material used in the show experiments was collected in late September, October, and November, 1913. It was kept in as near natural conditions as possible in running lake Michigan water with gases at saturation. Most of the material used had been collected within three or four days but in a few cases material one week old was used. Several of the species in question occur outside of habitats of the type from which they were collected for these experiments. These relations are given below.

Rapids Community.

Etheostoma and *Cambarus* occur among and under stones. *Goniobasis* on stones, *Hydropsyche* on and under stones. The remainder under stones.

Species, Usual Habitat Rapids	Occasionally in	Rarely in
Etheostoma coeruelum Raf.	Pools of streams	Lakes and large streams
Cambarus virilis Hag.	Lakes	Lake Mich. (Harris '03)
Goniobasis livescens Me.	Sandy bot lakes	Veg. pool (Shelford '13)
Hydropsyche sp.	Cn shells in moderate current	Veg. in moderate current

Argia putrida		
Perla sp.		
Heptageninae		Shores large lakes.
Psephenus		Shores large lakes.



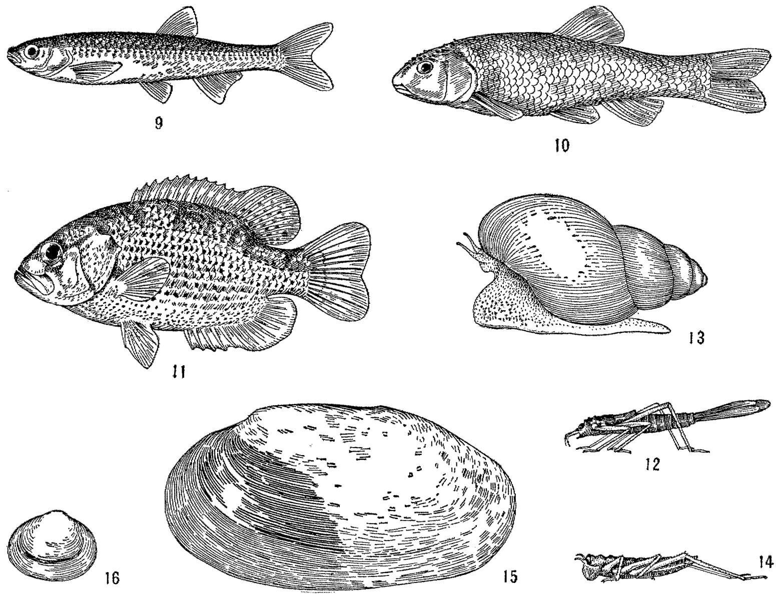
FIGS. 1–8. General form of rapids animals. Drawn on the same scale; all about natural size; seen from the side slightly above. 1, the rainbow darter (*Etheostoma coeruleum* Raf.); 2, crayfish (juvenile) (*Cambarus virilis* Hag.); 3, snail (*Goniobasis livescens* Mke.); 4, caddis worm (*Hydropsyche*); 5, damsel fly nymph (*Argia sp.*); 6, stone fly nymph (*Perla sp.*); 7, mayfly nymph (*Heptagenineæ*); 8, water penny (*Psephenus sp.*).

POOL COMMUNITY.

The fishes live in the open water or in the shade of the scattered vegetation. Calopteryx rests on the vegetation. The rest burrow in the bottom. The species studied were not selected carefully as representative but were merely collected from pools.

Species, Usual Habitat Sand-bottomed Pools,	Occasionally on or in	Rarely in
Notropis atherinoides Raf.	Mud bottom	Lakes and ponds (Forbes and Richardson '08).
Hybopsis kentuckiensis Raf.	Mud bottom	Lakes and ponds.
Ambloplites rupestris Raf.	Large streams.	
Calopteryx sp.		
Campeloma subsolidum Ant.	Mud bottom	Among vegetation.
Anodontoides ferussacianus Lea.	Lakes	
Sphaerium striatinum (?)	Lake Mich. (11 meters).	

Side views of each of the animals (Figs. 1–16) studied show the radically different ways in which the animals receive stimuli such as current, horizontal light, etc.



FIGS. 9–16. General form of the pool animals. 9, Shiner (*Notropis atherinoides* Raf.); 10, River chub (*Hybopsis kentuckiensis* Raf.); 11, Rock bass (*Ambloplites rupestris* Raf.) 12, Damsel fly nymph (*Calopteryx maculata* Beauv.); 13, River snail (*Campeloma subsolidum* Ant.) 14, Burrowing dragon fly nymph (*Macromia sp.*); 15, Mussel (*Anodontoides ferussacianus* Lea) 16, Small bivalve (*Sphaerium sp*). The fishes were juvenile. All are drawn cn the same scale.

III. REACTIONS TO CURRENT.

1. METHODS.

The tests were made in an Allee Straight Current apparatus, Fig. 17, the trough of which is 11 cm. wide, 7 cm. deep and 68

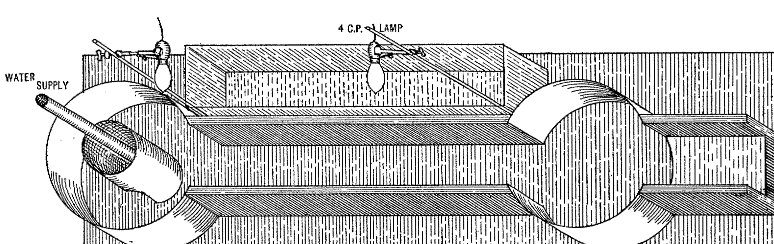


FIG. 17. Allee's straight current apparatus.

cm. long. Pieces of screen (32 meshes per inch) were placed across each end adjacent to the round reservoirs. The screens

confined the animals in the central portion of the apparatus. Thirty-three centimeters above the bottom of the trough and 12–15 cm. from the respective ends were two 4-c.-p. carbon filament lamps. The control box was placed alongside the current trough and kept cool by streams of water.

Water flowed into the left-hand well from the supply pipe. The rates of flow were determined by measuring the amount of water that flowed through the trough in cubic centimeters per second. This was divided by the average area of the cross section of the water flowing through the trough, which gives the velocity in cm. per second (Finley's method). The velocity is determined by (*a*) the volume flowing into upper well per unit of time, (*b*) depth of water in trough, and (*c*) angle of slope.

VELOCITIES USED AND FACTORS CONTROLLING THEM.

Volume per sec.	Depth in Cm.	Degrees Deviation from Level	Velocity in Cm. per Second
200–250 c.c.	4.0–5.0	0	4–6
500–600 c.c.	4.5–5.0	1	10–12
500–600 c.c.	2.5–3.5	2.5	16–20

With very few exceptions five individuals were used. In each case the animals were poured into the center of the trough and readings begun after the animals had adjusted themselves to the current. This time differed greatly with different species, to a less extent with different lots of the same species. The differences between different species are due largely to different speeds of movement. Variations of the second kind were in strong current and due to the particular way in which the animals floated against the lower screen. The length of time before the first reading is given in general terms for each species.

2. SPECIFIC PECULIARITIES OF BEHAVIOR IN WATER CURRENT.

(Time before first reading given in brackets.)

Rapids Community.

Etheostoma (Fig. 1) [15–30 sec.]. Rest on bottom head up stream, move by darts, positively thigmotactic, often rest against lower screen and often forced against it in very strong current.

Cambarus (Fig. 2) [15–30 sec.]. Creep on bottom.

Goniobasis (Fig. 3) [30–40 min.]. Amount of activity is largely

determined by current and light. Controls show little or no activity.

Hydropsyche (Fig. 4) [2–10 min.]. Strongly thigmotactic; the majority often did not leave the screen, and in some experiments they showed little positive orientation so several experiments were performed and an experiment which represented our general experience with them was selected for tabulation. Their tubes nearly always face the current in the rapids of streams (Wesenberg-Lund '11) and in experimental conditions where they are allowed to spin. They appear to have a greater efficiency in the current than any other of the species studied. When poured into a 60 cm. per sec. current, one out of three individuals succeeded in obtaining silk attachment and moved upstream 1 cm. per min. on a comparatively smooth wooden bottom. With the tubes once constructed they are secure against anything but floating objects.

Argia (Fig. 5) [2–5 min.]. Awkward in current. Orients well in very weak current due to large gill plates which act like a weather vane.

Perla (Fig. 6) and *Heptageninae* (Fig. 7) [5–30 sec.]. Both good runners; both crouch close to the bottom, especially the latter.

Psephenus (Fig. 8) [3–15 min.]. Slow to orient but very efficient in current.

Pool Community.

Notropis (Fig. 9) [immediately]. Swims constantly.

Hybopsis (Fig. 10) [immediately]. Swims and rests on bottom with head up stream.

Ambloplites (Fig. 11) [immediately]. Swims constantly; in strong current the fishes are thrown sidewise against the lower screen and cannot dislodge themselves.

Calopteryx (Fig. 12). Variable time to first reading—began when one left lower screen.

Campeloma (Fig. 13) [30 min.]. Good efficiency against current on account of large foot. Inactive in very strong current.

Macromia (Fig. 14). Apparently indefinite. Sometimes moving up or down in the trough; frequently resting for long periods ith the posterior end up stream.

Anodontoides (Fig. 15). Moves in the direction headed.
Sphærium (Fig. 16). Moves in the direction headed.

3. Method of Reading.

At the time of each reading the number of animals headed up stream within approximately 16 degrees of the direction of the current was counted positive. Those headed down stream were counted negative; those not falling within an arc of approximately 32 degrees of the total possible orientations for both positive and negative were counted as indefinite. Mollusks withdrawn *within their shells* and other animals *lodged against the screen* were counted as inactive or out of the experiment. Readings were taken fifteen seconds apart; fifteen seconds being sufficient time for individuals of all the species to orient at least once, most of them several times. In nearly all cases twenty readings were taken. With the exception of the snails, ten readings were taken, then the animals were disturbed, loosened from their footing, and after a short period they were read ten times again.

4. Progress Up Stream.

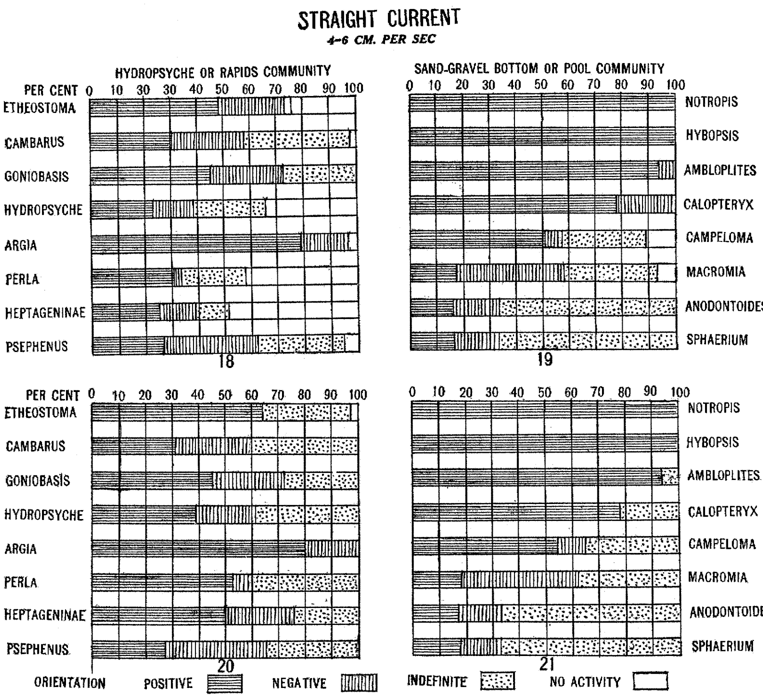
The preliminary experiments, especially those of Mr. Finley, showed that all the species make definite progress up stream. This results from (*a*) *positive orientation* and (*b*) movement. The amount of movement up stream differs for different species and for the same species under different conditions. Thus positive orientation, the first essential to up stream movement is the more significant.

5. Typical Results.

The diagrams illustrate typical *orientation* results, in per cent. of total. The upper diagrams (Fig. 18, 19, 22, 23, 26, 27) give per cent. positive, negative, indifferent and inactive (or on the screen, shown blank). Since inactive individuals and individuals on the screen cannot be regarded as responding to the current, the lower diagrams (Figs. 20, 21, 24, 25, 28, 29) give per cent. of *active* individuals showing positive, negative, and indefinite orientation. The data on the *active* individuals were used as a basis for comparison. Since *Anodontoides* and *Sphærium* move

in the direction headed, the diagrams are of perfect chance indefiniteness, counting an arc of thirty two degrees of the possible circle of orientation as covering respectively positive and negative trials.

Comparing first the reactions of the *rapids* animals to the different velocities, we note that the positive orientations in the

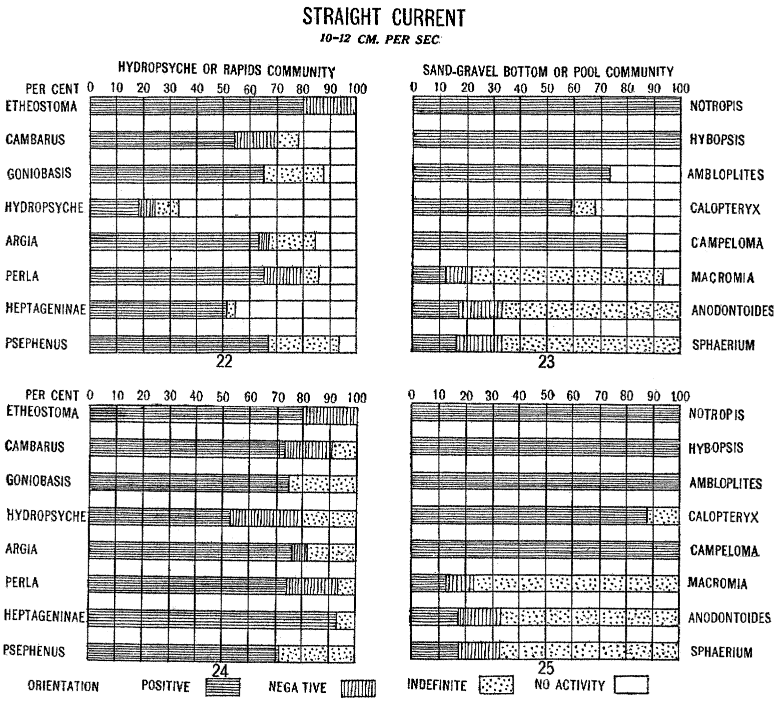


FIGS. 18–21. Showing reactions to 4–6 cm. per sec, current in per cent. positive, negative, indifferent, and inactive (18–19) and in per cent. *active individuals* positive, negative, and indifferent (20–21). The rapids community (18) shows a large percentage of inactivity while the percentage of active positive (20) averages less than 50. The animals of the pool community were nearly all active. The first four non-burrowing species are strongly positive. It thus appears that 4–6 cm. per sec. is near the optimum for pool species. Temperature of water in experiments: Rapids animals 16° C.; pool animals 9° C.

4–6 cm. per sec. current are only a little greater than the negative and indifferent, excepting *Argia* which is thrown into line by the action of the current on the gill plates. The amount of activity was different for the different species.

In the 10–12 cm. per sec. current positive orientations (Figs. 22–24) are increased at the expense of the negative and indefinite while the same difference is further emphasized in the 16–20 cm. per sec. current and this without any material increase in the number of individuals resting on the screen.

16–20 cm. per sec. represents the flow to which the swift stream species appear best adapted. In this current the per



FIGS. 22–25. Showing reactions to 10–12 cm. current in per cent. positive, negative, indifferent, and inactive (22–23) and per cent. of active individuals positive, negative, and indefinite (24–25). Here there is *more* activity among the rapids animals and *less* among the pool animals than in the 4–6 current. The percentage of active positive is much higher in the case of the rapids animals. Temperature as in Figs. 18–21.

cent. of active is more nearly the same for the different species (compare Fig. 28 and 24 with 20). These figures show a *remarkable uniformity of positive reaction,* over 93 per cent. for all but *Psephenus* and *Hydropsyche,* which are *most efficient* in clinging and less active otherwise. They are thus *ecologically equivalent* to the rest of the animals living under stones.

Comparing the *rapids* community with the *pool* community which was studied only briefly and the results added here to make the work on the rapids community clearer, we note that the greatest activity was apparently in the 4–6 cm. per sec. current (compare Figs. 19–23 and 27). None of the animals were washed against the screen. All were active except *Anodontoides*

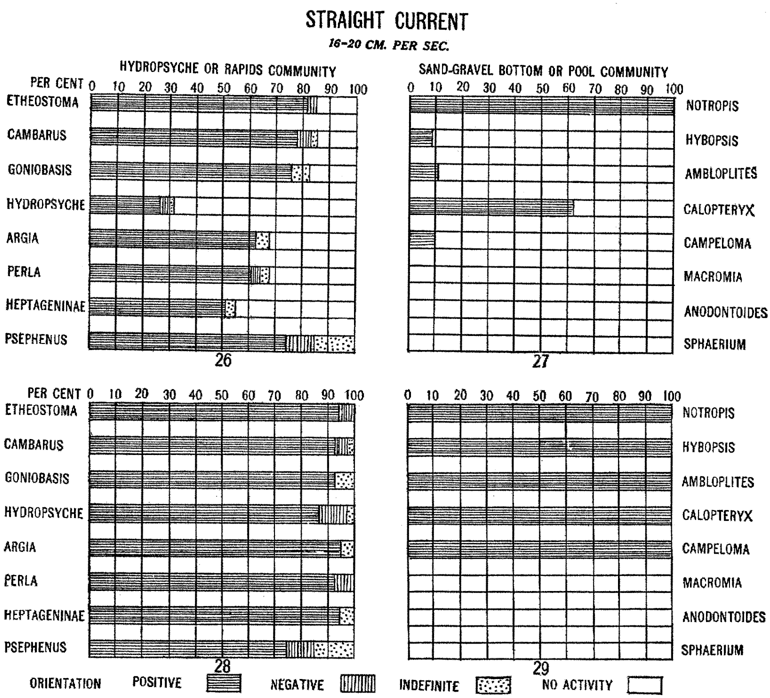


FIG. 26–29. Showing reactions to 16–20 cm. current in per cent. positive, negative, indefinite, and inactive (26–27) and per cent. of active individuals positive, negative, and indefinite (28–29). There was a large percentage of activity among the rapids animals and a small one among the pool animals, due in the case of the latter to inefficiency in the current. The rapids animals here show the greatest per cent. of active individuals positive (compare with Figs. 18–25). Temperature as for Figs. 18–20.

and *Sphærium*, which moved in course of 24 hours but in the direction in which they happened to be headed. The condition indicated in the diagram is for a chance orientation allowing 16 deg. on either side of the direction of the current as respectively positive and negative.

In the 10–12 cm. current (Fig. 23) the amount of activity still

remains large but the wide rock bass was forced against the lower screen. *Campeloma* was less active. *Macromia* and *Calopteryx* were washed against the screen. *Anodontoides* and *Sphærium* showed activity as usual.

In the 16–20 cm. per sec. current only *Notropis* held out against the current for the five minutes during which the readings were taken. The other fish were swept against the screen very soon as were the other animals except *Anodontoides* which was inactive. Thus judging from (*a*) the amount of activity, (*b*) the efficiency and (*c*) the number of positive orientations, the 4–6 cm. per sec. current is probably nearest the optimum for the pool community.

IV. REACTIONS TO BOTTOM.

1. METHOD.

The tests were made in a dead black dark room under a hood of black sateen which permitted observation from between the symmetrically placed 4-c.-p. lamps clamped in a narrow slit (Fig. 30). The experimental boxes were two bread pans 10x31x50

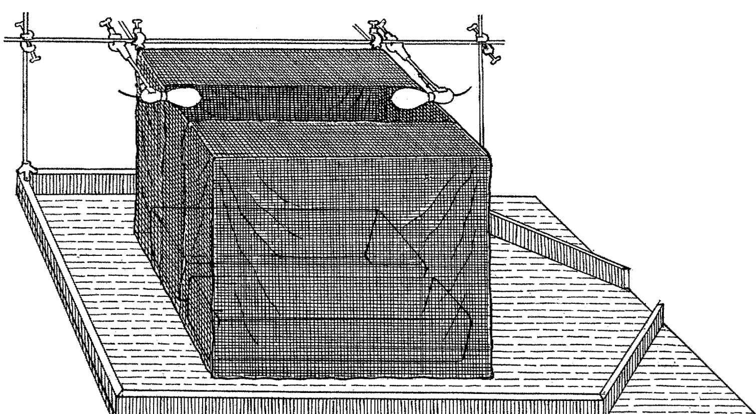


FIG. 30. Showing the water tray and hood in which the pans were placed in the study of reactions to bottom. The observations were made through the slit between the lights.

cm. The bottom of one was entirely covered with beeswax, one half of the other with sand and the other half with wax into which the Warsaw Co.'s quartz dust numbers ½, 1,

$1\frac{1}{2}$, 2, $2\frac{1}{2}$ had been beaten to give a surface like stone. These two pans were placed side by side beneath the lamps which were 25 cm. apart and 28 cm. above the bottom. Water flowed around the pans and kept them at a temp. of 14° C. Water in the pans 1 to 2 cm. deep.

2. Specific Peculiarities.

Rapids Community.

Etheostoma and *Cambarus* readings every 30 sec. begun at once.

Goniobasis: 40 watt tungsten lamps were substituted to increase activity and the experiment was read every half hour (due to inactivity). The animals were placed in a row on the boundary between sand and hard material, in some cases so that they would extend and come in contact with the sand in others, with the hard material. When they became active, they crept from the sand to the hard bottom in all cases and usually turned back when moving from the hard bottom to sand. The reaction to sand and hard bottom in this species was influenced by reactions to gravity because while the sand and hard bottom in the experiment were at the same level the foot settled into the sand enough to make the hard bottom higher and the mollusks tend to crawl upward. The results are legitimate because in their natural habitat the animals can avoid sand by this means.

Hydropsyche. Readings every minute, begun after 3 min. They often turned back on reaching the sand and were more active while on it.

Argia. Readings every minute, begun after three minutes.

Perla. Readings every minute, begun after one minute.

Heptageninae. Readings every minute, begun after one min. Turn back on reaching the sand.

Psephenus. Readings every minute, begun after five minutes. The animals are evidently much irritated by the sand as they wave the thin margins of their bodies about, walk high on their legs and when once in contact with the hard bottom they come to rest and cling for days if not loosened.

Pool Community.

Notropis, *Hybopsis*, and *Amblоplites* apparently do not react to bottom when in small experimental boxes.

Calopteryx does not react sharply to bottom in these tests as it clings in vegetation particularly in sand bottomed pools but is frequently found on sand bottom.

Campeloma, *Macromia*, *Anodontoides*, and *Sphærium*.—After creeping about for some time in the unnatural conditions of the experiment, come to rest, burrow in the sand, in most cases with a small portion of the body protruding. *Sphærium* burrows well only in the presence of a current.

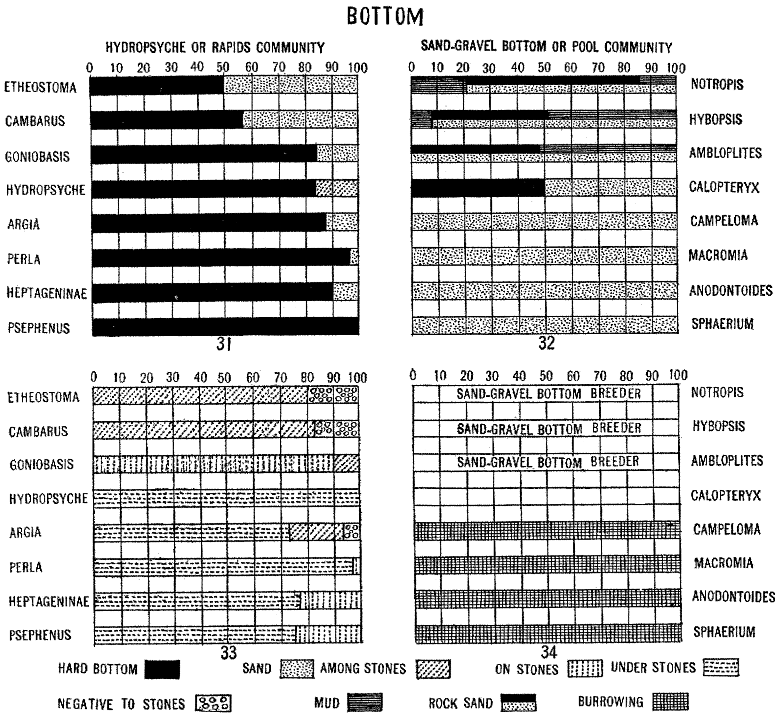
3. Typical Results.

In the rapids community we note that there is a striking avoidance of sand by the animals living below the stones; less striking by those living on and among the stones. There is then a general agreement in the preference for hard surface and avoidance of sand. The animals of the pools all show a large preference for sand especially those living on the bottom; *Calopteryx* in the preliminary experiments showed no preference for either end but is for some reason commonly associated with sand. Since the fishes did not react to bottom in such small space it was necessary to draw, by way of predicting the character of response, data calculated from collections by Forbes and Richardson ('08). Here relations to mud and sand and rock are not clearly separated but the preference clearly includes sand for the majority of cases. The data in Fig. 34 shows the extent to which the tabulated animals burrow.

4. Reactions to Stones.

The reactions of the animals to stones were tested in the apparatus described for the bottom experiments. Two pans with waxed bottoms were placed side by side under the hood. In one half of one was placed a number of irregular pieces of quartz 1 × 2 inches and a number of pieces about ¼ of an inch in diameter. Ten individuals of each rapids species were placed in each pan and left in entire darkness. A one candle power lamp was turned on for the readings. The percentage of animals found under, on and among stones is shown in Fig. 33. The preference for stones was strong. Only the darters, crayfishes and *Argia* showed an avoidance of the stones in 20 per cent. or

less of the trials. All the other species were among the stones, either on or under as indicated in the diagram.



FIGS. 31–34. Show the reactions to hard *vs.* sand bottom and to loose stones *vs.* wax bottom in per cent. of total. Fig. 31 shows the per cent. of rapids animals on sand and hard bottom, a large preference for the latter being evident. In the case of the pool fishes results of the experiments were unsatisfactory and as further tests had to be abandoned on account of cold weather the data of Forbes and Richardson ('08) is included to indicate what the probable results of experimentation will be. It will be noted that the preference is quite generally for sand, rock and mud occupying a much smaller portion than sand. Fig. 33 shows the relation to rocks on a wax bottom. Negative reaction to rocks is small. A striking agreement is shown in the general preference for stones. Fig. 34 shows the relation of the animals of the pool community to sand bottom with reference to burrowing. Here again the breeding data of the fish is taken from literature to indicate what might be found experimentally. Experiments performed at 14° C.

Fig. 34 shows further probable relations of the pool animals in such bottom experiments. The fishes usually bury their eggs and other species excepting *Calopteryx* bury the body in the sand.

V. REACTIONS TO LIGHT.

1. Specific Peculiarities—General Results of preliminary Experiments performed.

A large number of experiments was performed with light. Diffuse day light, tungsten lamps, Nernst lamps, with and without the cylindrical lens were used so as to obtain variations in direction and intensity. Since some of the animals react to intensity, some to direction and not to intensity, and since some readily *move* out of strong light while others tend to *stay out* of it, special methods were demanded.

The general characters of the reactions of different species are given below.

Etheostoma appears indefinite to light of the intensities used. Individuals make no recognizable response to either direction or intensity.

Cambarus does not react sharply to ordinary differences of intensity or to direction. In general they appear slightly negative to strong daylight often resting with the anterior end in the lighter parts. In an intensity gradient they back into the dark when the water or the apparatus are jarred which may account for their apparent negativeness, under experimental conditions in which the surrounding medium is disturbed. Finley found that they turn back from white paper used in making records.

Goniobasis appears positive to direction and to all intensities of room light when intensity accompanies direction and in Fig. 38 is believed to be less strongly positive than the animals usually are due to slowness of movement.

Hydropsyche is apparently indifferent to intensity; reacts positively to direction.

Argia does not react to intensity, orients negatively to direction reversing soon in some cases.

Perla starts into greater intensity and turns back; orients negatively to direction when a light is turned on.

Heptageninae—orient negatively to direction at first but quickly reverse in high intensity. Do not react clearly to intensity. Turn back on encountering strong light.

Psephenus is negative to direction, less so to intensity.

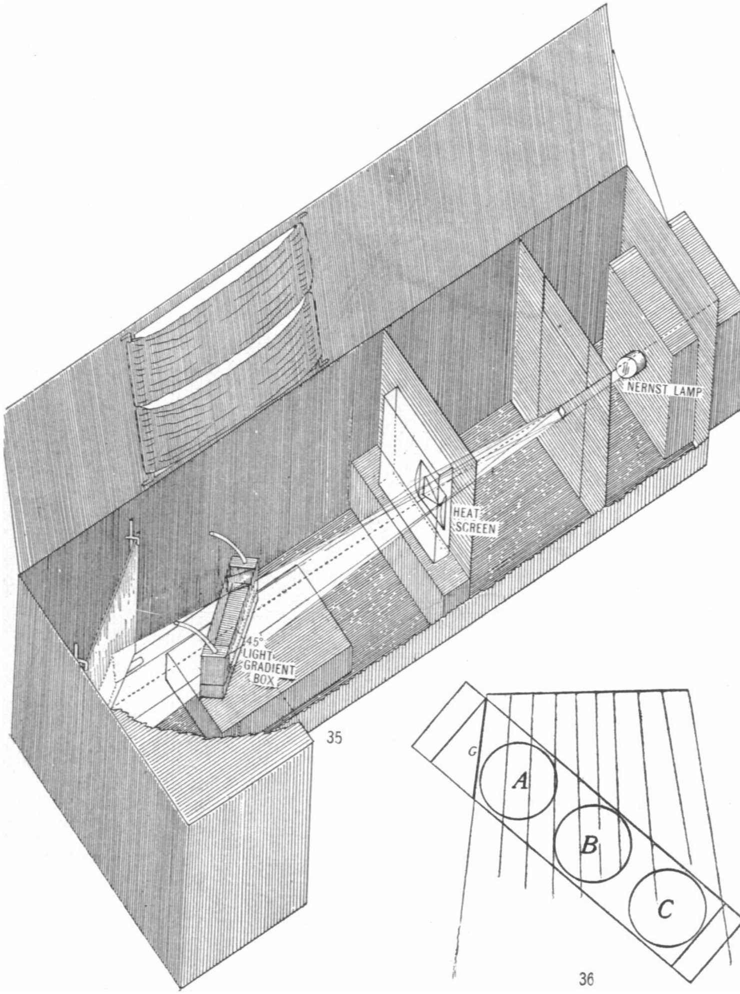


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FIG. 35. Shows the light grader in which the experiments were performed. It is in all essentials like that described by Mast ('11), p. 61. A 132-watt lamp was used. The heat screen of distilled water, the gradient box and reflecting mirror are shown.

FIG. 36. Shows the plan of the experiments. The light gradient was focused at the horizontal line and the rays diverged slightly as indicated by the diverging lines. *G* is the glass plate to confine the animals from the dark corner. *A*, *B*, and *C* are the positions in which the bottomless cylinder was placed to confine the animals, before readings. The portion of the box to the right of the *C* was in essential darkness.

Pool Animals.

Notropis swam quickly about but spent most of its time in the medium and light thirds.

The other two species of fish and *Calopteryx* spent most of their time in the darker third while the other species were not active.

2. Methods of Show Tests and Typical Results.

The final tests or show experiments were made in a Yerkes light grader such as is described by Mast ('11 p. 61), (fig. 35). A 132-watt Nernst lamp was used 50 cm. from the lens (with a triangle of 70 mm. base and 82 mm. altitude) and the experimental box (5 cm. wide by 25 cm. long) was turned at an angle of 45 degrees to the direction of the light and with the nearest corner at the focal point of the lens and at the left end of the gradient field. A glass plate (*G* of Fig. 36) was placed across the corner

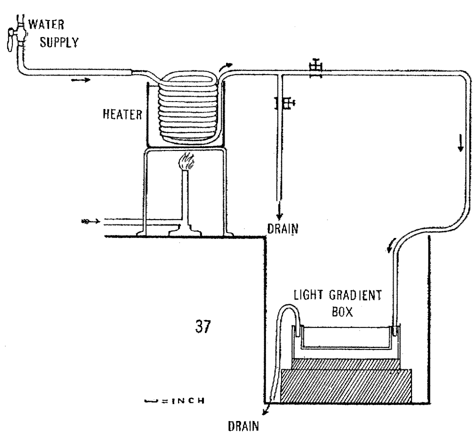
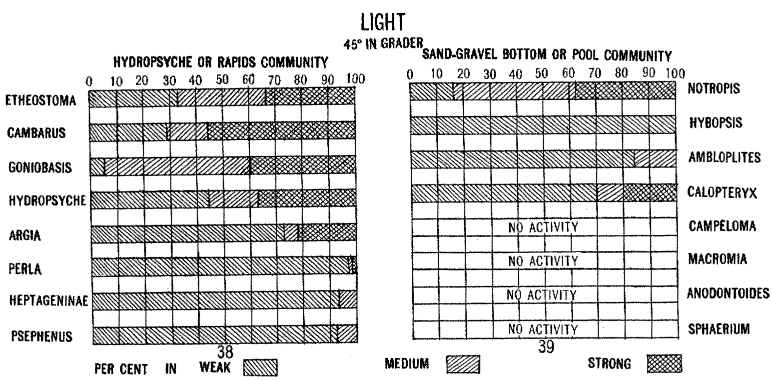


Fig. 37. Showing the relation of the hollow-walled glass-sided experimental box. The water came from the supply pipe, passed through the coil which rested in a vessel of water kept hot by a bunsen burner. The flow and gas were readily adjusted to give any desired temperature within experimental needs. The water passed from the coil to the hollow wall of the light box. It was necessary to empty the box often and when this was done the flow was temporarily turned out through the drain nearest the coil without changing the rate of flow.

to prevent the animals from moving into the darkness. The experimental box had glass sides and metal ends. All parts not made from glass were painted dead black and the light which

passed through the box was reflected by a 45-degree mirror into the end of the grader box against dead black paper. The experimental box was made from copper with hollow bottom and ends which could be attached to a water tap by means of a hose. (Fig. 37). The water in these tests was kept at 14°C. by passing it through a coil immersed in water kept hot by a Bunsen burner (Fig. 37).

Aside from the general facts stated below and culled from the preliminary experiments all the experiments were performed with 5 individuals of each species placed in the 45 deg. box in the following manner. A small board was placed in front of the lens so as to shut off all light from the experimental box. A bottomless glass cylinder just fitting inside the box was placed in the position *A* of Fig. 36. Five specimens were poured into the cylinder. A board with a hood and 1-c.-p. lamp which lighted the sheet of paper on which the records were made but which threw very little light into the room was used in recording



FIGS. 38 AND 39. Showing the reactions of the animals in the light gradient in percentage in the thirds. Note differences related to the level at which the animals live. Experiments performed at 14° C.

results and when all was in readiness the board in front of the lens was dropped and the cylinder removed in the same motion of the arm. Readings of the position of the animals in the thirds of the box were taken every 30 sec. up to a total of at least forty readings. In the case of some animals like *Psephenus* which move less rapidly after a short time, the number of readings was

increased and the time between them lengthened until the animals took up a characteristic position. The experiment was repeated with five other individuals confined in the center positions (*B* of Fig. 36) and again with five more confined in the dark portion (*C* of Fig. 36). The last 20 readings of each series *A*, *B*, *C*, were averaged to give the results shown in Figs. 38 and 39. In Fig. 38, we note that (1) the animals living under the stones in rapid water selected the darker portion of the gradient box; (2) *Hydropsyche* which is found under and on stones (in algæ) is less negative to the intensities used than those always under the stones; (3) *Goniobasis* which always lives on stones is more positive than any of the others; (4) *Cambarus* in these undisturbed conditions showed a slight excess percentage in the strongest light; (5) the darters were indifferent remaining in the third in which they were confined.

The animals of the pool community behaved very differently. *Notropis* was quite positive while the other fishes and *Calopteryx* which are associated with vegetation were quite negative. The Mollusca and *Macromia* were inactive.

VI. SUMMARY AND DISCUSSION.

Figs. 40 and 41 are introduced to show the character of the *agreement* and *disagreement* in the rapids community and the fact that the pool community is different and remains *unsolved.* Noting first Fig. 40, we see a noteworthy agreement in reaction to bottom (a preference for *hard bottom* which means *avoidance of sand*) and to current. Those living on or under stones (including *Hydropsyche* were found largely on stones in algæ) were under stones in general *darkness*. *Goniobasis* which lives on stones was found on stones in the experiments. *Etheostoma* and *Cambarus* which live among stones are found among stones. Thus we have vertical disagreement in the matter of relation to bottom. Turning to reactions to light we find a comparable difference. Animals living beneath stones show a preference for weak light, those on stones medium light, and those among stones strong light. If we were to study out the community in full we would find that reactions to many other factors would be of importance. The formation of associations (Wodsedalek, '12) no doubt is of

importance. There is agreement in reaction to factors of prime importance and disagreement in respect to factors differing strikingly in the different situations in which the animals are living within the community.

The diagram for the pool species is introduced to show how strikingly it differs from that of the rapids community. Though agreement is not indicated here, our experience with the reactions of pool fishes and invertebrates to chemical differences in water,

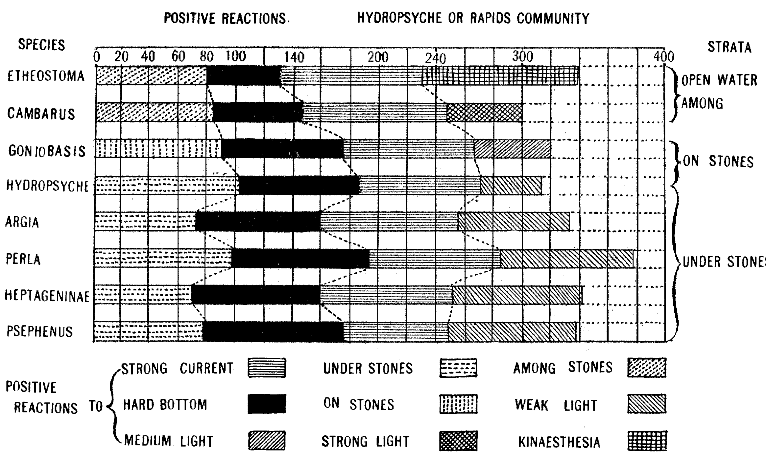


FIG. 40. Showing the agreement and disagreement of reaction of the rapids community. Note agreement of reaction to bottom and current and disagreement of two other reactions, related to the level at which the animals live. Each reaction is represented on a scale of 100 and if no other factors entered in the total should be 400 and the space all occupied. For strong agreement in positive reactions to stones see Fig. 33, p. 307.

suggests that such differences may be of much importance to all the species.

The difference emphasized by the presence of two types of reactions not shown in the other charts, namely, a strong preference for bottom involving sand (see Fig. 32 for details in case of the fishes) and burrowing which are reactions not shown by the rapids species at all. The non-burrowing species are positive to current, the burrowing species do not respond within ordinary lengths of time. The reactions to light show much more sharp negativeness than in the case of darters and crayfish. The community is clearly unsolved as far as agreement is concerned

and a large amount of experimentation would be necessary to determine suitable tests for these animals and then all the animals from both communities should be put through all the tests new and old. A series of new tests must be added for each new aquatic community and all the old tests must be so modified as to secure good response from all the animals. Thus the labor involved in comparing a number of communities is great.

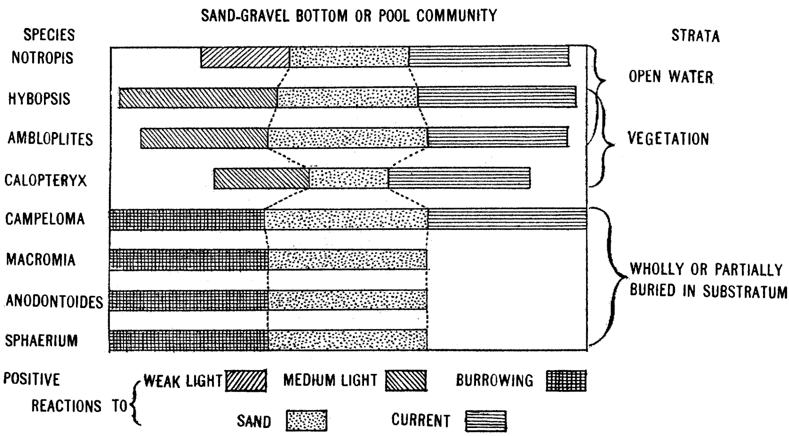


FIG. 41. Showing suggestions as to the probable agreement and disagreement of the reaction of the animals of the unsolved pool community on a basis of a total of 300, introduced to show the striking differences between communities.

VII. SUMMARY OF CONCLUSION.

1. The animals of an animal community are in agreement in the reaction to certain intensities of two or more factors. These reactions may be used to designate them. Thus the rapids community may be designated as *litho-rheotactic* meaning that the animals are arranged with reference to current and stones of considerable size.

2. Animals living in the *same* or comparable situations within the community habitat are in agreement with respect to factors not concerned in the general agreement and the animals of *different* situations react differently to these additional factors. Similar differences are the physiological basis for strata and consocies though the small number of species makes the latter not easily distinguishable here.

3. Single species found in any community occur in other situations where they are governed chiefly by stimuli toward which there is *not* agreement of reaction throughout the communty to which they primarily belong.

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